A SYMBOLIC COMPUTATIONAL FRAMEWORK ARCHITECTURE FOR AUTOMATING CONSTITUTIVE MODELING ENCAPSULATION

J. Michopoulos [a], **M. Lesoinne** [b], **F. Lechenault** [b], **P. Tsompanopoulou** [c], **E. Houstis** [c,d] and **, C. Farhat** [b]

[a] U.S. Naval Research Laboratory
Special Projects Group, Code 6303
Computational Multiphysics Systems Lab.
Washington DC, 20375
john.michopoulos@nrl.navy.mil

[b] University of Colorado at Boulder
Center for Aerospace Structures
Dept. of Aerospace Engineering Sciences
Boulder, CO 80309-0429
{michel,lechenau,charbel}@ colorado.edu

[c] University of Thessaly
Comp. Eng. & Telecommunications Dept.
38221 Volos, Greece
yota@inf.uth.gr

[d] Purdue University
Computer Sciences Department
W. Lafayette, IN 47906
enh@cs.purdue.edu

The architecture of a computational infrastructure for automated program synthesis of constitutive behavior modules required in developing a data-driven environment for multiphysics applications (DDEMA) is presented. The requirements for such a sub-system are presented in terms of the constitutive field theory derivation meta-process that is identified through the transition from conservation principles to field equations. The various necessary software components and their inter- and intra- relationship along with their positioning relative to the overall framework of DDEMA are identified.

The approach followed is based on the availability of massive data acquired from mechatronic multidimensional testing robotic frames that expose the material and structural systems to a vast stimulus space and allow the simultaneous acquisition of both the stimulus and response space samples. This in fact, determines the data-driven character of the approach and allows for the employment of inverse system identification methodologies that lead to capturing the material constitutive behavior. The mathematical tool that allows such an endeavor is a dissipated energy density function with free coefficients that are determined via constrained optimization yielding from the minimization of the difference between the experimentally measured and the analytically determined energy lost into the specimens under test due to damage leading to their nonlinear behavior.

Key technologies utilized are custom and commercial packages within “Mathematica’s” symbolic rewriting engine context, various Java application-programming interfaces (APIs), and various dialects of the extensible markup language (XML) and associated technologies. Specifically, tensor transformation algebra is handled by the “MathTensor” package; constitutive and field equations derivations are assisted through the theorem proving capabilities of the “Theorema” package; custom authored packages integrate the usage of all other packages and are used to generate or splice source code within existing templates of classes utilized to implement constitutive behavior within existing finite element codes; integration of “Mathematica’s” symbolic capabilities with the Java based framework of DDEMA is achieved through “J/Link” Java API interface; inter-modular, intra-application, and inter-application data exchange along with state archiving and unarchiving are achieved through extensive utilization of XML import/export technologies such as the “Data Junction” applications suite.

The role of the data-driven symbolic infrastructure for capturing the constitutive response of the various material systems is discussed from its final utility perspective of being realized within PDE discretization solution methodology such as finite element modeling as it is relevant for DDEMA .

Acknowledgement
The authors acknowledge the support by the National Science Foundation under grant EIA-0205663.